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temperature ranging between 64° and $85^{\circ}7$. In every instance it was warmer, the greatest difference being $6^{\circ}6$.

11. Eleven observations of *Valeriana tuberosa* in comparison with grass.

The mean gives the Valerian $0^{\circ}5$ warmer than grass; the temperature ranging between $52^{\circ}6$ and 73° . In seven instances it was warmer than the grass, the greatest difference being $3^{\circ}3$.

[In the last four examples the temperature at night, and the maximum with black bulb are included, so that the former will tend to lower the result and the latter to raise it.]

XI. "Reduction and Discussion of the Deviations of the Compass observed on board of all the Iron-built Ships and a selection of the Wood-built Steam-ships in Her Majesty's Navy, and the Iron Steam-ship 'Great Eastern';" being a Report to the Hydrographer of the Admiralty. By FREDERICK J. EVANS, Esq. Communicated by the Lords Commissioners of the Admiralty. Received May 5, 1860.

(Abstract.)

The analysis of the deviations of the compass in this paper comprises the observations made in forty-two iron ships, varying in size from 3400 to 165 tons, a selection of wood-built screw and paddle-wheel steam-vessels, as also the steam-ship 'Great Eastern' at various times prior to her departure from England.

The observations made in the iron-built ships extend over periods varying between thirteen and five years; and having been made with the same description of compass—the Admiralty standard—and under similar conditions of arrangement and situation, in accordance with the system carried out in Her Majesty's Navy, details of which are given, the general results are strictly comparable.

In the analysis of the Tables, amounting to nearly 250 in number, of deviations observed in various parts of both hemispheres, the formula deduced from Poisson's General Equations by Mr. Archibald Smith, given in the Philosophical Transactions for 1846, p. 348, has been employed.

In this formula, the deviation of the compass on board ship,

reckoned positive when the north point of the needle deviates to the east, is given by the following expression :—

$$\text{Deviation } (\delta) = A + B \sin \zeta' + C \cos \zeta' + D \sin 2\zeta' + E \cos 2\zeta',$$

ζ' being the azimuth (by compass) of the ship's head, reckoned from the magnetic north towards the east ;

A, D, E being constant coefficients depending only on the amount, quality, and arrangement or position of the iron in the ship : B and C, coefficients depending on these, and also on the magnetic dip and horizontal intensity, are each consisting of two parts ; one caused by the permanent magnetism of the hard iron, the deviation produced by which varies inversely as the horizontal force at the place ; and the other, caused by the vertical part of the earth's force inducing the soft iron in the ship, the deviation produced by which varies as the tangent of the dip : B representing that part of the combined attraction acting in a fore-and-aft direction, C that acting in a transverse, or athwart-ship direction.

From the equation $\tan \frac{-1}{B}C$, the direction of the ship's force, and $\sqrt{B^2 + C^2}$, the total magnetic force of the ship in proportion to the horizontal force at the place of observation is obtained : for convenience, 1000 has been adopted to represent the value of the earth's horizontal force at the English ports of observation, in order, by an easy comparison, to note the changes on foreign stations.

By comparison of the coefficients of the several descriptions of ships, it is observed that in wood-built steam-vessels, the coefficients B and C vary nearly as the tangent of the dip ; from whence it may be inferred, as a general rule, that in steam machinery permanent magnetism bears but a small proportion to induced ; but in iron-built ships, B and C generally vary more nearly as the inverse horizontal force, showing that they depend more on the permanent magnetism of the iron of the ship, and thus confirming the view of the Astronomer Royal, given in his earliest deductions (Phil. Trans. 1839), that the effect of transient induced magnetism is in these ships small comparatively. Numerous examples are given in detail of this permanency of magnetism, as also of the gradual diminution of the ship's force resulting from time.

An investigation of the coefficient D, which is caused entirely by the horizontal induction of the soft iron in the ship, and which is

known as the “quadrantal” deviation, shows, that while in wood-built steam-ships it seldom exceeds 1° or $1\frac{1}{2}^\circ$, it rises in iron-built ships from $1\frac{1}{2}^\circ$ to 6° and 7° ; the Liverpool Compass-Committee recording even a point of the compass.

The chief characteristics of the quadrantal deviation, as developed in this investigation, are—

1. That it has invariably a positive sign, causing an easterly deviation in the N.E. and S.W. quadrants; and a westerly deviation in the S.E. and N.W. quadrants.

2. Its amount does not appear to depend on the size, or mass of the vessel, or direction when building; or on the existence of iron beams.

3. That a gradual decrease in amount has occurred, after the lapse of a number of years, in nearly every vessel that has been observed.

4. That the value remains unchanged in sign and amount, on changes of geographic position.

5. That a value not exceeding 4° , and ranging between that amount and 2° , may be assumed to represent the average or normal amount in vessels of all sizes.

Numerous examples are given in support of these propositions, as also of the uniformity of the amount of quadrantal deviation when determined in various parts of the ship; and, assuming the normal amount in iron steam-ships as from 2° to 4° , an analysis is given by which it is seen that 75 per cent. of the iron ships of the Royal Navy are included in this condition.

Two questions of importance here arise; are the results of this analysis conclusive, and if so, under what conditions do large quadrantal deviations occur? Reverting to the Astronomer Royal's early experiments in 1838–39, in the iron ships ‘Rainbow’ and ‘Ironsides,’ whose values were very small, and presuming that those vessels were built of good material—from their then experimental character—as also that similar conditions of material of good quality exist in the iron ships of the Royal Navy, it is assumed that the value (2° to 4°) represents the average condition of a ship built of the best or superior iron.

On the other hand, can the inference be drawn that large quadrantal deviation in an iron ship implies that inferior material has been used

in her construction? Attention is here directed to the ships ‘Birkenhead’ and ‘Royal Charter,’ which from their well-known magnetic coefficients may be regarded as the types respectively of “hard” and “soft” iron constructed vessels, and from their consideration, as also from a review of the general results, these conclusions are derived:—

1. That in an iron ship of ordinary dimensions, a standard compass can be placed, the deviations of which will but little exceed those obtaining in wood-built steam-ships; and further, that on changes of geographic position, however distant, these deviations will be within smaller limits, and can be approximately predicted.

2. A divergence from these conditions will arise when the inductive magnetism of the hull or machinery predominates; and it is inferred, especially from the example of the ‘Royal Charter,’ that large quadrantal deviation and fluctuating sub-permanent magnetism (due to hull alone) are co-existent, and give rise to conditions of compass disturbance which are beyond prediction, and which have hitherto baffled inquiry and given a complexion to theoretical deductions varying as regarded from different points of view.

In order to examine the change which the original magnetism of an iron ship undergoes after launching, a series of compass observations were made in the steam-ship ‘Great Eastern’ prior to her quitting the River Thames in 1859, and subsequently at Portland, Holyhead, and Southampton*—at the three first-named places within short periods of time of each other.

The results, from an Admiralty Standard Compass placed in a position the least subject to influence from local masses of iron, were as follows:—In the first five days, from Deptford to Portland, the ship’s force had diminished from 0·585 to 0·480 [the earth’s force = 1·000], or nearly one-fifth; representing a decrease in the “semi-circular” deviation from $35^{\circ} 50'$ to $28^{\circ} 45'$; the direction of the force, or neutral points, approaching the fore-and-aft line by 10° , or changing from 47° on the starboard bow to 37° .

At the expiration of the next six weeks, the ship in the interim having made the passage to Holyhead, the ship’s force diminished from 0·480 to 0·390, or about one-sixth, corresponding to a decrease

* The observations at Southampton were made after the paper was communicated to the Royal Society, and are introduced by way of supplement.

of "semicircular" deviation from $28^{\circ} 45'$ to $23^{\circ} 0'$, the direction of the force changing from 37° to 32° .

At Southampton, in June 1860, or nearly eight months after the experiments made at Holyhead, the force had further diminished from 0.390 to 0.235, or by one-half, corresponding to a decrease in the "semicircular" deviation from $23^{\circ} 0'$ to $13^{\circ} 30'$; whilst the direction of the force approached the fore-and-aft line 25° , or from 32° to 7° ; the quadrantal deviation remaining nearly constant [$+4\frac{1}{4}^{\circ}$] the whole time included in the various observations.

The unvarying tendency of the direction of the ship's force in the 'Great Eastern' to assume a fore-and-aft line, supports the view that time, with the vibrations and concussions due to sea service, leads to a distribution of the magnetic lines, of the nature of a stable equilibrium depending on the average of the inducing forces to which the ship is exposed; the respective sections of the hull having north and south polarity, being separated by lines approximating more nearly a horizontal plane and vertical axis through the body of the ship; instead of the inclined axis and equatorial plane of separation due to the magnetic dip of the locality, and divergence from the magnetic meridian, of the hull while building.

The practical information resulting from the example of the 'Great Eastern' is, that prior to a newly built iron ship being sent to sea, her head during equipment should be secured in an opposite direction to that in which she was built; and that the magnetic lines should be assisted to be "shaken down" by the vibrations of the machinery in a short preparatory trip prior to the determination of her compass errors, or their compensation; but especially that in the early voyages vigilant supervision should be exercised in the determination of the compass disturbances.

Another important point, generally neglected when compasses are adjusted by the aid of magnets in a newly built iron ship, is rendered manifest by the results of this investigation; namely, the necessity of the errors of the compass being determined and placed on record prior to the adjustment. Without the knowledge to be derived from these observations of the magnetic force of the ship, all future changes of magnetism and consequent errors of the compass are mere guesswork both to those who adjust, and those in charge of the navigation of the ship.

It is recommended that, in any future legislation for the security of the navigation of our mercantile marine with reference to iron-built ships, the determination and record of these preliminary observations should be secured.

The paper concludes by directing attention to the general principles of practical import which result from the investigation, viz. as to the best direction with reference to the magnetic meridian for the keel and head of an iron ship to be placed in building, to ensure the least compass disturbance; the best position and arrangement for a compass to ensure small deviations, and permanency on changes of geographic position; and the changes to which the compass is liable from various causes on the foregoing conditions being fulfilled.

For the best direction in building, it is shown that, from the nature of the polarity of the hull, and especially of the top sides in the after section of the ship and adjoining the compass, where usually placed, the latter is least affected in those vessels built in the line of the magnetic meridian.

For iron steam-vessels engaged in the home or foreign trades in the northern hemisphere, it is recommended, from the then antagonistic magnetic influence of the hull and machinery, to build them head to the north: for iron sailing vessels, from the top sides, in the usual position of the compass, being magnetically weak if built head to the south, the latter direction is to be preferred.

The selection for the position of the compass depends on the direction of the ship during building; in those built head to north, it must be removed as far from the stern as convenience will permit; in those built head to south, as near to the stern as convenient, but avoiding especially, in all cases, proximity to vertical masses of iron. In ships built head east or west, there is little choice of position: in those built on the intercardinal points, a position approximating to the stern when the action from the top-sides—to be determined experimentally—is at a minimum, is to be preferred.

Ample elevation above the deck and exact position in the middle line of the ship, are primary conditions to be observed; and no compass should be nearer iron deck beams than 4 feet. As every piece of iron not forming a part of, or hammered in the fabrication of the hull, such as the rudder, funnel, fastenings of deck houses, &c., is of a magnetic character differing from the hull of the ship, proximity to

any such should be avoided, and, as far as possible, the compass should be so placed that they may act as correctors of the general magnetism of the hull.

As most compasses are affected by the magnetism of the ship to an amount depending on their elevation, and the direction of the ship in building, the disturbances will be large comparatively, except in those vessels built head east or west.

A series of Tables is appended, wherein the magnetic coefficients and ship's force and direction of the various classes of vessels are given, the ships being classed according to the nature of their material and machinery.

XII. "On the Sources of the Nitrogen of Vegetation; with special reference to the Question whether Plants assimilate free or uncombined Nitrogen." By J. B. LAWES, Esq., F.R.S.; J. H. GILBERT, Ph.D., F.R.S.; and EVAN PUGH, Ph.D., F.C.S. Received June 21, 1860.

(Abstract.)

After referring to the earlier history of the subject, and especially to the conclusion of Saussure, that plants derive their nitrogen from the nitrogenous compounds of the soil and the small amount of ammonia which he found to exist in the atmosphere, the Authors preface the discussion of their own experiments on the sources of the nitrogen of plants, by a consideration of the most prominent facts established by their own investigations concerning the amount of nitrogen yielded by different crops over a given area of land, and of the relation of these to certain measured, or known sources of it.

On growing the same crop year after year on the same land, without any supply of nitrogen by manure, it was found that wheat, over a period of 14 years, had given rather more than 30 lbs.—barley, over a period of 6 years, somewhat less—meadow-hay, over a period of 3 years, nearly 40 lbs.—and beans, over 11 years, rather more than 50 lbs. of nitrogen, per acre, per annum. Clover, another leguminous crop, grown in 3 out of 4 consecutive years, had given an average of 120 lbs. Turnips, over 8 consecutive years, had yielded about 45 lbs.

The graminaceous crops had not, during the period referred to,